M.O. 533 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 79, No. 939, SEPTEMBER 1950

TORNADOES OF MAY 21, 1950

By H. H. LAMB, M.A.

Introductory.—Tornadoes are intense whirls of small diameter in which the inflowing wind rotates (usually cyclonically) and feeds a strong vertical current at the centre, capable of lifting men, beasts and heavy objects, and in which the maximum horizontal velocities may exceed hurricane force. The great wind velocities, the twisting effects associated with the exceptional horizontal gradients of velocity and the extremely localised development of great pressure differences, amounting to an appreciable fraction of normal atmospheric pressure, all combine to make this the most violent of atmospheric disturbances.

For a tornado to occur, conditions favouring the development of violent vertical convection, as in thunderstorms, must exist. Thunderstorms and tornadoes may therefore be regarded as associated phenomena. Further, conditions must enable the development of violent up-currents right down to ground level. For this a system of strongly converging winds is necessary, a system most easily developed where there is a maximum of horizontal shear, and spinning, sometimes at high velocity, can be set off. The development of the strong vertical current at low levels is also favoured by high humidity and a low condensation level. It appears that topographical features may provide the trigger by local sharp accelerations of the horizontal winds as a front or shear line advances.

In America it has been found that only warm sectors of unstable tropical air from the Gulf of Mexico produce tornadoes[1]*, a fact which explains the overwhelming predominance of tornado tracks orientated from south or south-west to north or north-east. In Europe the situations giving rise to tornadoes usually (but not always) involve unstable, warm and moist southerly or south-westerly air streams.

Destructive tornadoes are uncommon in the British Isles though relatively most frequent in the broad English lowlands and river basins. Fifty occurrences have been noted either in the *Meteorological Magazine* or in the publications of the Royal Meteorological Society since 1868, with trails varying in length from a few hundred yards to over a hundred miles, the longer trails being always intermittent. It seems certain, however, that short trails of damage caused by similar phenomena in open country must occur more often than reports are received. The main tornado, formed in Buckinghamshire on May 21, 1950,

*The index numbers refer to the list of references on pp. 255 and 256.

ranks amongst the three worst in our records of the past 82 years* and its track was amongst the longest recorded here or on the continent of Europe[4].

Tornadoes are much more common in the United States, especially in the great plains and in the Mississippi basin. In most years over 100 are reported in the United States[5]. 1949 was a record year with 290 occurrences; of these only about ten per cent., however, did damage equalling or exceeding that caused by the worst English tornadoes. Loss of life is a common accompaniment, and the fact that no human deaths were caused by the Buckinghamshire tornado must be considered fortunate.

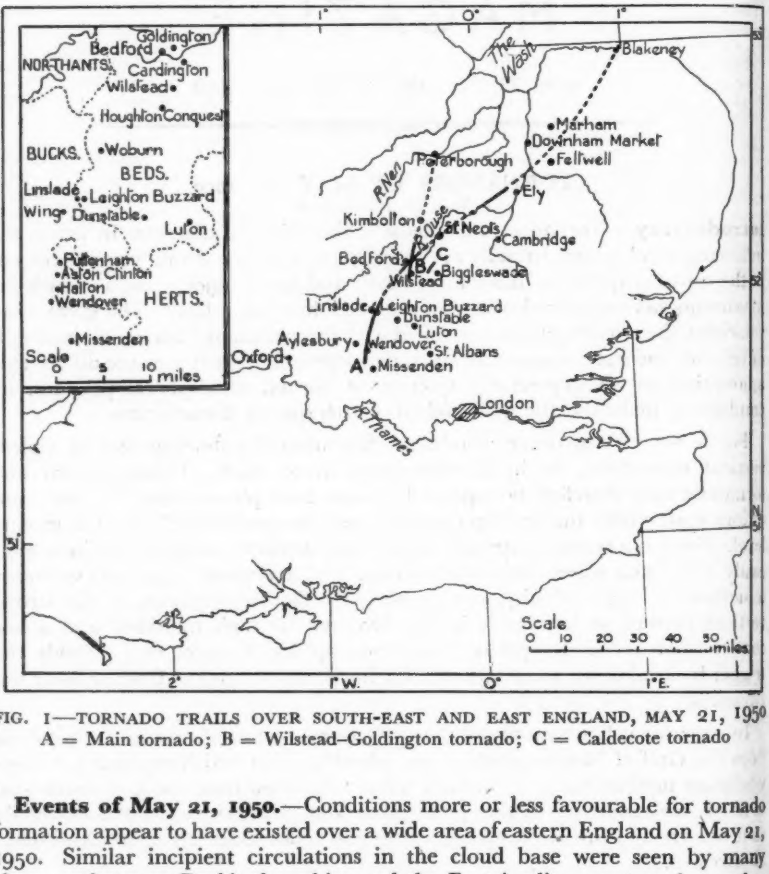


FIG. 1—TORNADO TRAILS OVER SOUTH-EAST AND EAST ENGLAND, MAY 21, 1950
A = Main tornado; B = Wilstead–Goldington tornado; C = Caldecote tornado

Events of May 21, 1950.—Conditions more or less favourable for tornado formation appear to have existed over a wide area of eastern England on May 21, 1950. Similar incipient circulations in the cloud base were seen by many observers between Buckinghamshire and the East Anglian coast, and, together with the remarkable convergence of the cloud motions feeding into these circulations, constituted a visibly threatening aspect of the thunderstorms from about 1400 G.M.T. onwards. Altogether three tornadoes left trails of damage, though one was short and another mainly in open country; the great bulk of the damage, estimated at over £50,000, was done by the remaining one along a 65-mile track from Wendover to the fens near Ely (Fig. 1).

*The other comparable cases were on October 19, 1870[2] and October 27, 1913[3].

Losses totalled £25,000 in Linslade, Bucks, alone, where some fifty houses were unroofed and a brick-built bakery demolished (see photograph between pp. 260 and 261). In the country full-grown trees were felled and others had their tops twisted off, trunks up to a yard thick being severed more or less cleanly. Many fruit trees were damaged and at some places whole orchards were uprooted. Farm buildings were shattered and lighter structures (such as chicken coops) and Nissen huts carried away and destroyed. The floor of one hut was left spiked on to the topmost branches of a neighbouring elm. Vehicles, including cars and farm carts with animals in them, were lifted and thrown about. Sheets of corrugated iron were carried distances up to half a mile and killed two cows. Over 500 chickens were lost. Telephone lines and wireless and television aerials were broken and power lines interrupted.

Apart from the Linslade-Leighton Buzzard area the places worst hit by the tornado were Wendover, Halton, Aston Clinton, and Puttenham, the outskirts of Bedford and Sutton near Ely (see photographs facing pp. 253 and 268 and between pp. 260 and 261).

All three tornadoes probably had their origins near the northern edge of the Chiltern Hills, the main one first appearing in the Missenden-Wendover Valley a little before 1600 G.M.T. and suddenly increasing the breadth and scale of its destruction at Wendover where the valley opens on to the Vale of Aylesbury. In a field just south of Wendover full-grown elms and walnut trees were felled over a width of 50 yd. and left lying in all directions. Passing over Wendover town the trail narrowed again, lifting the tiled roofs of old buildings, and after raising a column of water from the canal the tornado proceeded for a mile or so in less violent form. It was regenerated at Halton Camp (see photograph facing p. 252), where the heavy roof of the power station was lifted, and beaten nettles and battered trees registered the full counter-clockwise rotation of the storm. The twisting cloud column was seen to break up as it passed over a close avenue of chestnut trees across its path, and the evidence suggests that a ground whirl somewhat separate from the upper part of the column continued for the next 300 yd. or so.

Approaching Aston Clinton the revolving cloud was first seen 200 ft. clear of the ground, but soon lowered to the downhill slope and began to damage trees and buildings. Here for the first time the path performed several zigzags, influenced apparently by the configuration of dense coppices in the park but never going more than 200 yd. from its main course.

Over the up-slope to the ridge at Wing, some miles further on, the tornado zigzagged rather more, and at one stage broke into three or four columns, which reunited as it surmounted the eastern end of the ridge and bore down upon Linslade with redoubled fury. Even here the trail of damage did not depart more than 400 yd. from the general line.

The trail was in most places only 5–7 yd. wide, but broadened temporarily at Wendover, Linslade, near Bedford and at Sutton to 40 or 50 yd. Objects carried up in the twisting column were, however, strewn over a width of fully 200 yd. in places.

As is usual with tornadoes, all three on this day passed through successive cycles of regeneration and decay, often at about 5-min. intervals. Considerable distances were skipped entirely or passed over with the funnel cloud seen not reaching to ground level.

Nearly all the main bursts of energy occurred just north of a ridge of higher ground. After Linslade which was hit about 1630 G.M.T., the distances skipped became longer, and the tornado was probably tending to weaken as the highest temperatures of the day were past. Nevertheless two major regenerations took place over the low-lying, humid regions near the Ouse at Bedford and as late as 1830 G.M.T. over the fens near Ely.

Apart from these evident ground controls, the tornado travelled at about 24 m.p.h. in agreement with the wind at the 600–700-mb. level* (10,000–14,000 ft.) towards the north-north-east accompanied by a severe thunderstorm. Lightning and hail also caused damage, and took a toll of life amongst men and animals. Individual hailstones over 2 in. in diameter were picked up at two places on the actual track over which the tornado passed, and moderately large hail fell to considerable depths afterwards, especially at places just west of the track. Flooding also interrupted traffic on the Great North Road and on many roads in the Ouse and Nene Valleys and the Vale of Aylesbury.

After the main tornado had been in existence for an hour or so a widening cyclonic circulation was noticeably developing around it, establishing light westerly winds up to 50 miles south of the centre and carrying a sharp clearing front through from west to east; temperature dropped sharply with the heavy rain and hail preceding this front and remained some 10°F. lower than before; the sky cleared. This growing cyclonic circulation seems to have been continuous with that of a small depression in the North Sea next day, reaching Sweden on the 23rd, and travelling with the thermal wind over the centre.

Beyond Ely no further damage was reported, but the funnel cloud was seen at intervals lowering and then withdrawing into the cloud base. Over Feltwell, approaching the escarpment which forms the eastern limit of the fenland, it was broken up into dozens of smaller vortices 1,500 ft. above the ground but later re-formed again and was last seen over the sea off Blakeney, Norfolk. The thunderstorm was severe along this line, especially over the escarpment between Feltwell and Marham.

The subsidiary tornadoes formed 10–20 miles farther east, travelled north-north-east with the wind about the 600-mb. level and never developed a wider circulation. One damaged a few roofs and one tree at Caldecote near Biggleswade, Beds. The other passed along a 6-mile track from Houghton Conquest and Wilstead to Goldington near Bedford doing considerable damage. Near Bedford its track crossed the path of the main tornado, and points south-east of the town felt both. The major one was only 8–10 miles away (south-west) at the time, but no coalescence took place. The subsidiary tornado did no damage north of Goldington parish but the swirling cloud was seen as far north as Kimbolton, Hunts; its progress was accompanied by a distinct maximum of rainfall and other thunderstorm activity which continued to Peterborough, where the fire brigades were at work all night dealing with severe damage caused by flooding and lightning.

Meteorological circumstances.—*In the immediate neighbourhood of the whirl.*—No instrumental records from the immediate path of these tornadoes have come to light, though the Cardington anemometer and barograph were within 1½ miles of the two principal ones and have registered the effects of both (see Fig. 2). More striking tornado barograms are shown by Shaw[6], who

*See Table I.

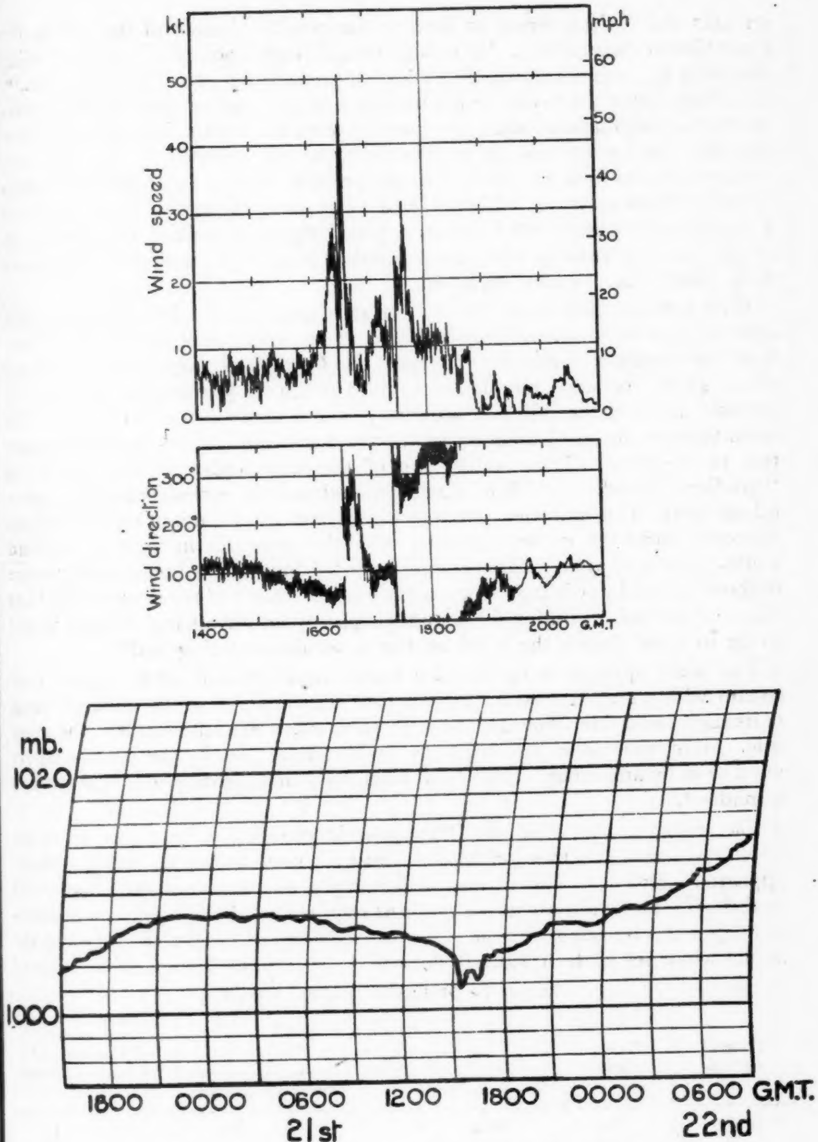


FIG. 2—AUTOGRAPHIC RECORDS FOR CARDINGTON, MAY 21, 1950

The maximum gust of 51 kt. occurred at 1632 as the Wilstead tornado (B on Fig. 1) passed, ¾ mile away. The second maximum at about 1705 is probably the passage of the major tornado (A on Fig. 1) about 1½ miles away, causing structural damage in south Bedford.

The maximum gust of 31–32 kt. at 1740 probably marks the clearing ront.

The barograph clock was nearly ¾-hr. slow.

remarks that " there seems no limit to the possible descent of the pen in the more violent examples . . .". Indeed the adiabatic cooling necessary to bring the cloud to ground level would indicate a pressure fall of at least 20–30 mb.[7]*, and if we accept the height of the unbroken water-column raised in the water-spout as a rough and ready water barometer measuring the pressure difference between the centre and its surroundings pressure may drop 200–300 mb. within a foot or so of the centre. In the present instance the Wilstead tornado raised a water column at Chapel End Farm near Houghton Conquest from a duck-pond between two barns in a peculiarly good position for gauging its height, and the unbroken column reached at least 10 ft., indicating a pressure drop of the order we have supposed.

With pressure profiles of this sort the maximum wind velocities must affect areas of extremely narrow cross-section and become almost meaningless apart from the gradients of velocity involved. The Cardington anemometer recorded about 40 kt. for some minutes around 1630 G.M.T., $\frac{3}{4}$ mile from the nearest tornado (actually the Wilstead subsidiary) and a maximum gust of 51 kt. The main tornado about $1\frac{1}{2}$ miles away at 1710 G.M.T. only raised the anemometer pen to 15–17 kt. These values are of the same order as the theoretical " gradient " wind, in which friction is ignored and the cyclostrophic term plays a large part. This indicates that velocities of 200–250 kt. might well have been measured near the centre, agreeing with the estimates in various standard works. The most violent damage appears to be done by the great local pressure differences and by twisting. It is mainly lee-side walls and windows which blow out, and the safest position for a man caught by an advancing tornado is said to be to stand facing the wind against a windward-facing wall[8].

The whirl appears to consist of a vortex superimposed on the general air stream with which it travels. In this case therefore the south-westerly winds of its right-hand side would be about 40 kt. stronger than the winds of the other side. Many more trees and objects were battered down by the south-westerly wind than by any other. This is said to be a common feature also of American tornadoes[8].

The general weather situation.—The synoptic situation is best seen from the re-analysed map for 1500 on May 21, just an hour before the main tornado appeared (Fig. 3). The corresponding upper air maps are not reproduced as there is some doubt about the patterns required to fit the Liverpool observations, but the morning map at 700 mb. (see *Daily Aerological Record*) and the actual winds set forth in Table I show that the tornado formed in a region of

TABLE I—OBSERVED UPPER WINDS

Time of ascent	Pressure level	Observed upper winds				Tornado area. Vector mean of Larkhill and Downham Market upper winds	
		Larkhill		Downham Market			
G.M.T.	mb.	°true	kt.	°true	kt.	°true	kt.
1400 (before tornado)	500	213	25	200	32	207	28
	700	168	34	201	32	185	33
	850	133	19	194	25	172	21
	950	123	15	155	15	139	14
2000 (after tornado)	500	185	36	192	31	189	33
	700	194	25	205	30	201	27
	850	205	21	228	30	216	25
	950	228	12	277	20	259	15

* Båth also uses this approach.

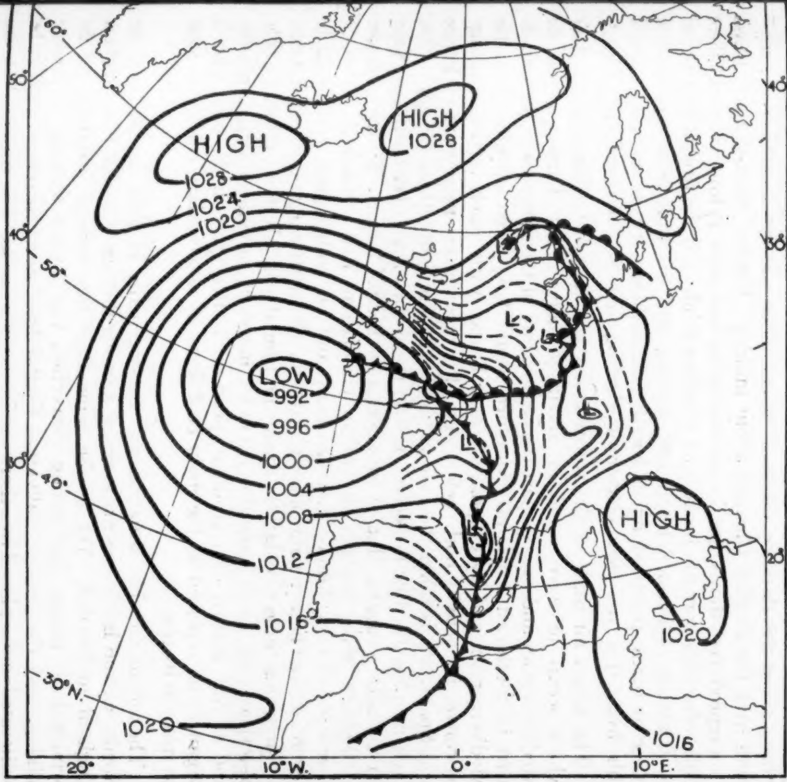


FIG. 3—SEA-LEVEL SYNOPTIC CHART, 1500, MAY 21, 1950

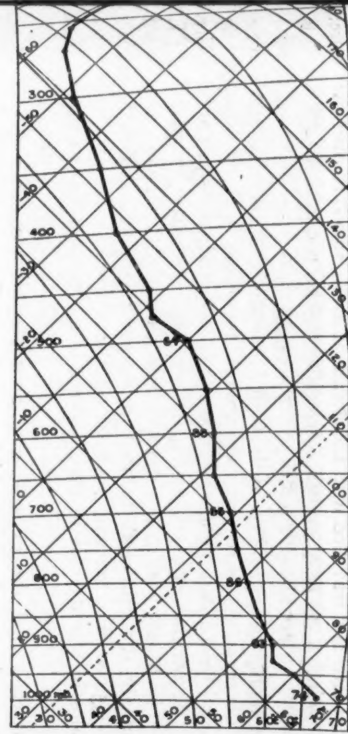


FIG. 4—LARKHILL UPPER AIR TEMPERATURES, 1500, MAY 21, 1950
Humidities are indicated in bold figures

diffluent flow and travelled with the stream at about 10,000 ft. over the centre: similar winds may have prevailed over the region in question right down to the frontal surface about 950 mb. (2,000 ft.).

The tephigrams (see Fig. 4) indicated instability for saturated air in the warm air mass, which reached the ground at Larkhill in the warm-sector tip for a short time about the afternoon ascent with temperatures just approaching 70°F. and which was over-running the tornado area where maxima of 64°F. were only briefly attained. Cumulonimbus cloud development could, and presumably did, proceed to the tropopause ; though this was at only 32,000–35,000 ft., distinctly lower than the extreme values in some other situations in recent years in which severe thunderstorms drifted up from the south.

It is clear that the extreme conditions on this occasion must rather be related to the low level at which great instability and vertical currents of saturated air were occurring and to other features such as the horizontal fields of wind and temperature. The frontal structure was not easy to follow, and to discover a significant association between it and the tornado requires exceptionally close analysis. We note, however, that the thunderstorm in which the main tornado occurred was located over a warm-front surface within 50–100 miles north-east of its point of occlusion. A group or line of thunderstorms about this distance ahead of the cold front was first located by "sferic" plots over the English Channel about midday. Vertical cross-section analysis (not reproduced) shows that the warm-front surface was very low over the Chiltern Hills where the tornado broke out; at points southward the frontal surface had been almost obliterated by ground heating and the front was very hard to place at many points along its length. Nevertheless it was essentially out of this front that the new cold-front clearing line was created—see Fig. 5.

The warm air mass in the warm sector was unstable African tropical air which seems to have come in about 30 hours from Tunisia across the Mediterranean and over or past the eastern end of the Pyrenees to the tornado area in south-east England. Moisture would have been acquired over the Mediterranean and by evaporation over France with much vertical exchange by convective activity both before and after crossing the mountains of France and Spain. As is often the case in similar synoptic situations troughs of low pressure early became noticeable within the warm sector over north-east Spain on the 20th, probably due to lee effect and thermal factors. By the afternoon of the 21st many troughs and minor circulations had developed within the warm sector over France and Germany and on both fronts, and might be regarded as a characteristic of the air stream. (By destroying the even alignment of the fronts these circulations made the frontal analysis more difficult.) The historical cold front from the Atlantic, however, advanced fairly regularly and at very slightly over gradient speed until after 1500 on the 21st, when it began to be replaced as the main cold front by a secondary cold front some 50 miles in its rear.

The broad weather situation was frontogenetic, in that the col over the North Sea and Baltic was maintaining a strong thermal gradient from southern England to Sweden. Yet at the same time the vertical instability of the principal air masses and strong convection was always tending to produce mixing, and the various individual frontal lines were therefore liable to be obliterated and replaced by others within 100 miles or so. The trailing occlusion

Reproduced by courtesy of Home Counties Newspapers Ltd.

THE MAIN TORNADO APPROACHING HALTON R.A.F. STATION

The rotating funnel cloud was just lowering to the earth when the picture was taken and within the next few minutes a heavy roof in its path was lifted.

(see p. 247)

Reproduced by courtesy of H. H. Lamb

TORN AND BROKEN TREES AT SUTTON, ELY

The trunk in the foreground was 34 in. in diameter

(see p. 247)

of the depression over Norway (shown on the *Daily Weather Report*) or its associated upper front (still partly traceable on the vertical cross-sections over England) seems to have set off the first thunderstorms over southern England on the morning of the 21st; this occlusion line was really obliterated by afternoon, though a surviving portion traceable over East Anglia and acting rather as a warm front is indicated on Fig. 5. The main warm front itself was hardly traceable after the appearance of the tornado which swept part of the front back and generated therefrom a cold front in a new orientation. The exact position of this new front may have been affected by the cooling produced by heavy rainfall along the path of the thunderstorm with which the tornado was associated (see the rainfall map, Fig. 6, which betrays the tracks of the two

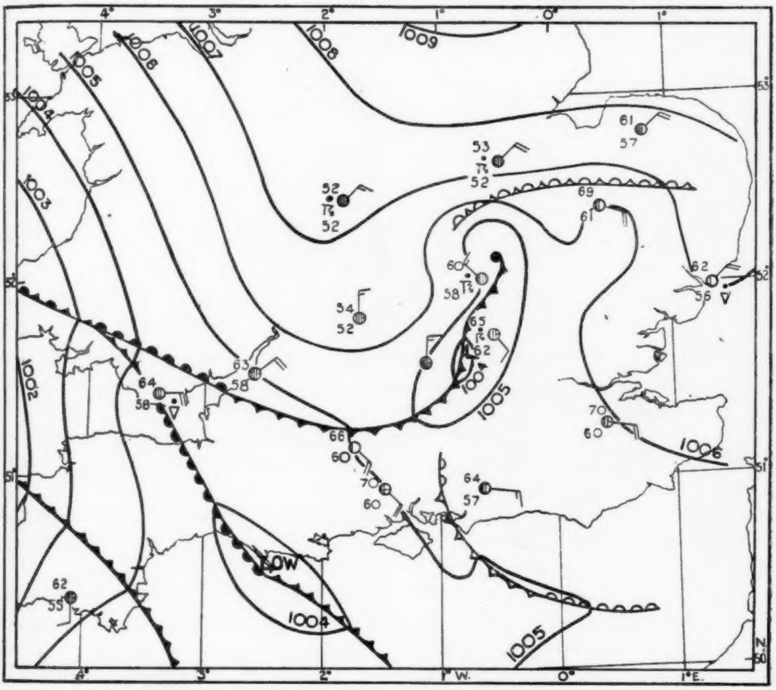


FIG. 5—SEA-LEVEL SYNOPTIC CHART, 1700, MAY 21, 1950

main tornadoes). At Dunstable, for instance, 10 mm. of rain fell in ten minutes and the thermogram shows a temperature drop of 10°F. with the onset of the hail. Nevertheless, this front merely represents a new configuration and a sharpened state of the boundary between the cool air from the North Sea and the warm air streams from the south and south-west.

On the 20th thermal "lows" had developed over southern England and Ireland. By the 21st, however, the general pressure gradient had increased, as the main Atlantic low moved northwards from the Portuguese coast to a point near 50°N. off south-west Ireland; on this day, therefore, it was only over eastern England, nearest the col over the North Sea, that a thermal trough and

later a thermal low could develop, appearing first about 1400 G.M.T. between Cambridge and London as a small feature seen only on the largest-scale maps. In the trough the preliminary thunderstorms became severe, and as pressure on the approaching thundery warm front became lowest at the point nearest this trough it may actually have initiated a deformation which aggravated the thunderstorms over this part of the frontal surface where the tornado developed and which produced the orientation of the new clearing front. The shear between the surface easterly current and the over-running warm air, already indicated by the winds tabulated in Table I, was progressively increased by this preliminary trough diverting the surface winds over Buckinghamshire gradually to northerly. The surface current from this direction came abruptly into play in the neighbourhood of the northern face of the Chiltern Hills.

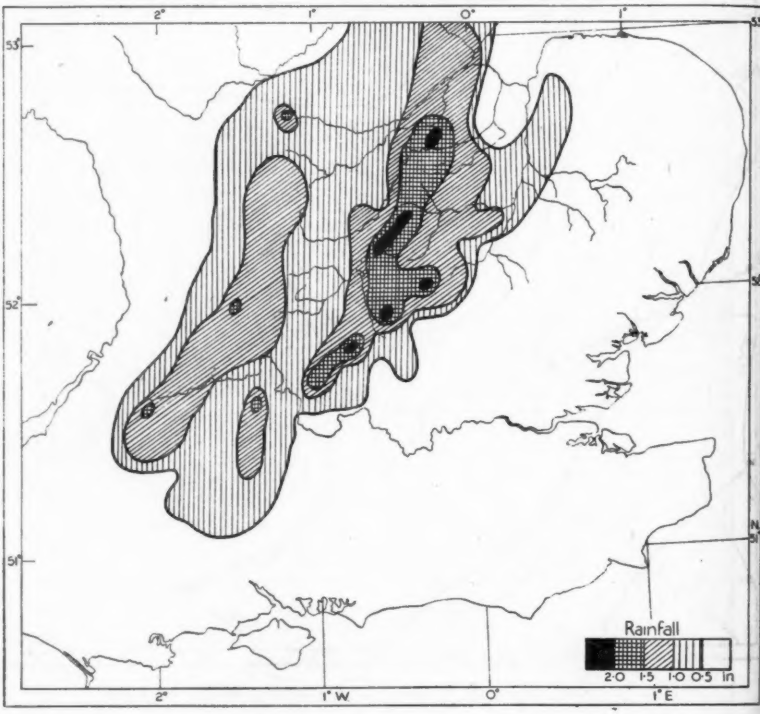
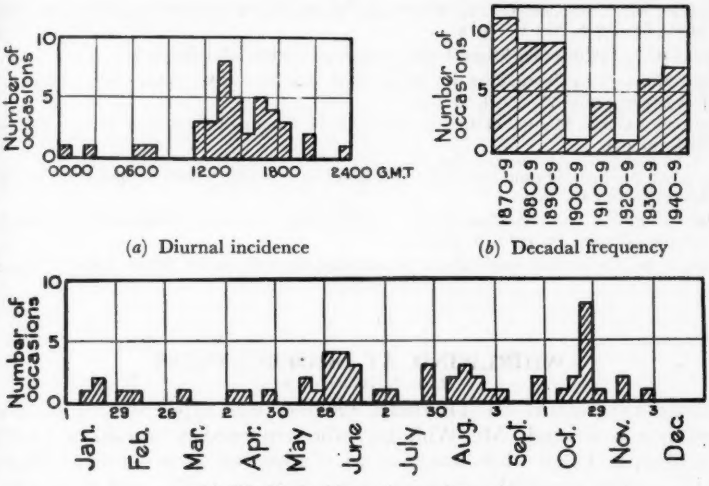


FIG. 6—RAINFALL DURING THE 24 HR. COMMENCING 0900, MAY 21, 1950

The isochrones of the clearing front following the tornado show an initial discontinuity with those of the historical (*i.e.* Atlantic) cold front farther west which can be explained in this way. By next day over the Low Countries, however, the two had probably amalgamated.

The incidence of tornadoes in the British Isles.—Apart from the geographical distribution to which we have referred the fifty cases of destructive tornadoes since 1868 have been examined to find their diurnal, annual and decadal incidence (see Fig. 7) and the accompanying weather situations.



(*a*) Diurnal incidence (*b*) Decadal frequency

(*c*) Weekly incidence (annual trend)

FIG. 7—DIURNAL, SECULAR AND ANNUAL TRENDS OF THE OCCURRENCE O DESTRUCTIVE TORNADOES IN THE BRITISH ISLES, 1868-1950

The " number of occasions " refers to total occurrences between 1868 and 1950

The decadal distribution shows a marked minimum frequency in the years 1900–29, when the general westerlies are believed to have been most prevalent, followed by greater frequency again in recent years. The annual distribution shows that destructive tornadoes can occur in any month*, but are most common in October; no less than eight of the fifty having occurred in the week October 23–29 associated with the best known cyclonic singularity of the year. The other main groupings are about the onset of the European summer monsoon (late May to mid June) and about the time of maximum summer thundery cyclonic situations (late July to mid August)[9]. The diurnal range of frequency shows the expected afternoon and early evening maximum associated with the peak of instability in the lowest air layers.

Examination of the general weather situations showed that most cases were frontal, especially associated with cold fronts and warm sector tips, though a proportion as in the present case showed no very obvious frontal association or formed in thunderstorms on over-running frontal surfaces, particularly near the warm-sector tip aloft. All the winter cases (November–March) were associated with general gales and considerable shear, those in the other months were much more variable in these respects. One case (August 21, 1889, in Shropshire) occurred in an unstable north-westerly current of gale force, but with no apparent frontal structure, coming over the mountains of Wales. In every case the situation is believed to have shown cyclonic curvature or cyclonic shear at the edge of a strong air stream over the region affected.

BIBLIOGRAPHY

1. GAIGEROV, S. S.; Synoptic conditions accompanying tornadoes in the United States during 1884. *Bull. Amer. met. Soc., Milton Mass.*, **21**, 1940, p. 229.
2. Anon. The squall of October 19th. *Symons's Met. Mag., London*, **5**, 1870, p. 149.

*None were reported in December, but there was one on November 30.

3. London, Meteorological Office. The South Wales tornado of October 27, 1913. *Geophys. Mem., London*, **2**, No. 11, 1914.

4. WEGENER, A.; Wind- und Wasserhosen in Europa. Braunschweig, 1917.

5. WOLFORD, L. V.; Tornadoes in the United States during 1949. *Mon. Weath. Rev., Washington D.C.*, **77**, 1949, p. 335.

6. SHAW, SIR NAPIER; Manual of meteorology, Vol. II, Comparative meteorology. Cambridge, 1928, p. 359.

7. BATH, M.; An investigation into three tornadoes in Sweden. *Medd. Upsala Univ. met. Inst., Stockholm*, Nr. 10, 1946.

8. WARD, R. de C.; The tornadoes of the United States as climatic phenomena. *Quart. J. R. met. Soc., London*, **43**, 1917, p. 317.

9. LAMB, H. H.; Types and spells of weather around the year in the British Isles. see p. 263.

WHIRLWIND AT SHOEBURYNESS

By L. G. HEMENS, B.Sc.

At about 1415 G.M.T. on Thursday, October 20, 1949, Shoeburyness was visited by a whirlwind. Mr. Whitaker, who happened to be outside his office at the time, said that while watching what appeared to be a frontal cloud he heard a muffled sound like distant thunder or an explosion, and on turning to the south-west saw that at a distance of about 1,000 yd. the air was filled to a considerable height with leaves, twigs and similar light debris swirling violently as though after a large but smokeless explosion. He called out two other observers, Messrs. Dunning and Chester, who saw the subsequent events with him. Almost at once the wind increased to gale force, torrential rain began to fall, and the debris, now quite dense and only a few hundred yards away, was travelling towards them from a south-westerly direction and was observed to be rotating from left to right, *i.e.* counter-clockwise. The disturbance very quickly arrived where they were standing. Tall trees in leaf were bent over and thrashed about wildly, and one or two broke. These trees had trunks about 1 ft. in diameter and were about 30 ft. high in a row across the path of the disturbance. A large corrugated-iron roof, held fast at both ends on a nearby shed, billowed up and down like a shaken sheet at a rate of about two vibrations per second. The shed was about 40 ft. by 20 ft. with one side open to the wind, and it was only about 20 yd. away from the observers, looking south-west, who were now standing in an opening of another three-walled shed, the roof of which, fortunately, was more secure. The air was filled with flying debris, gravel from road surfaces and large driving raindrops, all flying past at high speed, and with this there was a continuous loud rushing noise, loud enough to drown the noise of the flapping corrugated-iron roof and the breaking trees. About 30 yd. to the north-east from where they were standing, a large gabled wooden roof was ripped off a brick building and scattered in portions about 40 yd. down wind in a north-easterly direction; one portion was precariously balanced for a time against the chimney stack of an adjacent small building. This was neither seen nor heard while it was happening as the attention of the observers was held in the direction from which the debris was coming. The disturbance was all over in about a minute and the heavy rain ceased almost at the same time. The damage was confined to a narrow track about 100 yd. wide or less.

Damage was done at other places on the track of the disturbance, more especially to trees, light structures and temporary buildings, and there was considerable danger from flying debris and light articles of all sorts, such as

sheets of corrugated iron, or gravel, lifted by the wind and carried along at high speed in the wind.

The track of the damage shows that the whirlwind followed an almost straight path although there is evidence of some sinuosity. The direction of travel was from 235° true towards 55° true. The path of the whirlwind is shown in Fig. 1. No estimate could be made of the speed of travel. There is no evidence of how long it was in existence before entering the Shoeburyness area from the Thames Estuary nor of how long it continued after it was last observed from Havengore travelling up the coast towards Foulness.

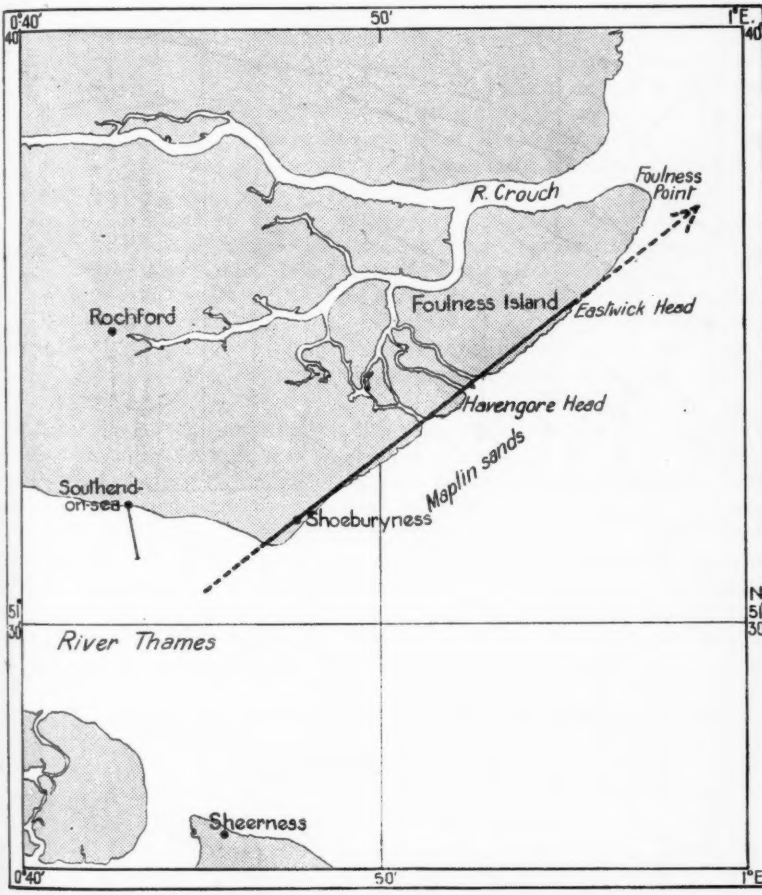


FIG. 1—PATH OF THE WHIRLWIND, OCTOBER 20, 1949

Records of the wind velocity are shown on the anemogram for the day from the Dines pressure-tube anemograph on top of the conning tower (effective height 89 ft.) adjacent to the north-east end of the central office building and situated on the south-east edge of the track of the damage (see Fig. 2). The

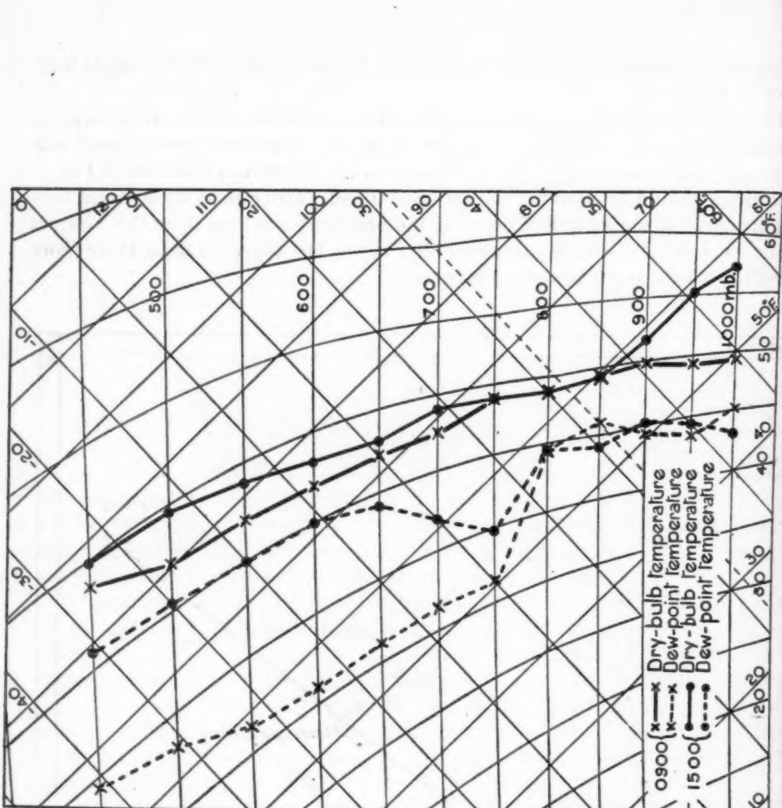


FIG. 3—UPPER AIR SOUNDINGS, DOWNHAM MARKET, OCTOBER 20, 1949

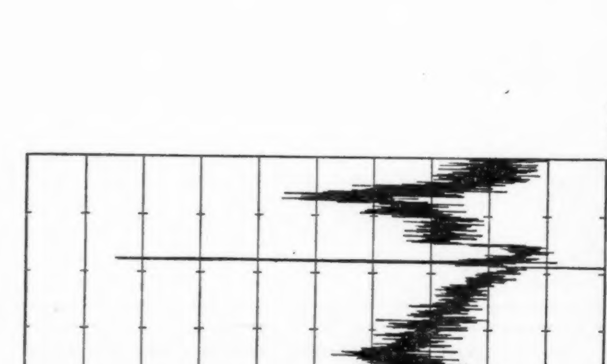


FIG. 2—AUTOGRAPHIC RECORD OF WIND SPEED AT SHOEBURYNESS, OCTOBER 20, 1949

anemograph is an electrical distant recorder. The direction unit was, however, defective and the direction trace is unreliable, although the velocity trace on the distant record is good. The trace accompanying this article is the record from the clock-drum on the float chamber housed at the top of the tower. The interesting feature of the record is that it shows that the wind during the disturbance consisted practically of a single gust rising suddenly to 85 m.p.h. from a mean wind speed of about 16 m.p.h. and dropping equally suddenly back again to about 20 m.p.h. As regards the direction of the wind, the general impression amongst observers is that the general wind direction was from SW. up to the time of the gust, that it then veered to about W. for about 20 min., and subsequently backed again to SW. No information is available as to any large and rapid changes of direction during the actual passage of the gust, due to vortical motion, but the impression is that the wind which did the damage was travelling from SW. in much the same direction as the direction of travel of the disturbance itself. Another feature of the velocity record is that the disturbance occurred in the lull between two squalls, the mean wind in the first reaching a maximum approaching gale force about $1\frac{1}{2}$ hr. before the whirlwind and in the second a maximum above gale force about 1 hr. after the whirlwind.

The synoptic charts for the day show that there was a strong, large-scale circulation of polar air around an extremely large low-pressure system with a family of three centres, one south of Iceland, one between Iceland and Norway, and the third over Lapland. Polar air from the north of the centres extended in a wide sweep over the Atlantic and penetrated as far south as lat. 40°N. before turning north-eastwards towards the British Isles and north-west Europe. Trailing cold fronts were indicated along the southern fringe of the low-pressure area.

The morning at Shoeburyness was mild, and there was continuous sunshine up to about 1230 G.M.T. with a wind of about 15–20 m.p.h. from SW. and about 1 okta of cloud, a few scattered showers and very good visibility. The cloud increased to 3 oktas about midday and there was a temporary increase of wind to about 35 m.p.h. from SW. (maximum gust 47 m.p.h.) at about 1230 with a slight shower. The wind decreased slowly to 16 m.p.h. from SW. by 1400 and the cloud increased to 7 oktas, cumulonimbus, fractocumulus, altocumulus and altostratus. A few minutes before the passage of the whirlwind and within a mile in advance of it, a roll cloud was observed below and attached to the leading edge of a cumulonimbus cloud and extending broadside across the wind. The whirlwind passed at about 1415, and a later report from an observer in an open situation farther up the coast described it as a vertical column of leaves and debris extending upwards and merging into a small downward bulge of cloud lower than the rest of the clouds. After a lull from the W. for about 20 min. after the whirlwind, the wind rose from SW. and increased to a squall of about 45 m.p.h. (maximum gust 56 m.p.h.) at about 1510 with considerable rain and some thunder. Subsequently, for the rest of the day weather was overcast with intermittent light, moderate and heavy showers, visibility very good and the mean wind continuing for some hours between 20 and 30 m.p.h. from SW. and decreasing slowly towards midnight. There were reports of heavy rain and flooding at Rochford and Hockley about 5–8 miles to the north-west of Shoeburyness but no times or details are available.

During the passage of the disturbance the barograph in the meteorological staff office recorded a fall of 4 mb. and a rise of the same amount immediately

after, the upstroke on the trace being superimposed on the downstroke. It is doubtful, however, to what extent this fluctuation of pressure is an indication of the fluctuation of static pressure in the vortex. The pressure and suction effects on the windward and lee sides of the building, due to a wind gust of 85 m.p.h. would be considerable, and the reduction of pressure on the lee side may have been communicated inside the room through an open door or window. The barograph also shows small rapid changes of pressure of about 1 mb. associated with the squall which occurred after the whirlwind.

The temperature and humidity records from the instruments exposed under standard conditions on the north-west edge of the track of the damage, and from the instruments on top of the conning tower, do not show any noteworthy change of temperature during the passage of the disturbance. The instruments, however, are rather sluggish. After the passage of the squall at about 1530 there was a fall of temperature of about 4°F. in half an hour. The relative humidity, which had been steadily increasing before the disturbance, increased abruptly from about 80 to 85 per cent. at the time of the disturbance, probably due to the rain.

The profiles of temperature and dew point aloft at Downham Market at 0900 and 1500 are shown in the accompanying tephigram (Fig. 3). At 0900 there was a layer of moist air up to about 7,000 ft. with a lapse rate about or slightly more than the saturated adiabatic. Above this the air was very dry with a lapse rate greater than the saturated adiabatic, there being a sharp discontinuity of the dew point at about 7,000 ft. At 1500 the temperature near the surface had risen about 8°F. and the lapse rate was near the dry adiabatic up to about 4,000 ft., above which the lapse rate was about the saturated adiabatic, and the dew point was very much higher than at 0900.

It is evident that the disturbance was a whirlwind of the tornado type. The cumulonimbus clouds, thundery showers, squalls and the Downham Market temperature and humidity profiles provide ample evidence of the instability associated with tornadoes, and in this connexion the presence of a thick layer of moist air below dry air is noteworthy. The presence of a quasi-stationary cold front in the vicinity, which also appears to be a necessary condition, is probable but less certain. The occurrence of the whirlwind in the region between two squalls of the type more usually associated with unstable moist air may be worthy of note.

ABSOLUTE DROUGHTS OF AUGUST 1947

By J. GLASSPOOLE, M.Sc., Ph.D and H. ROWSELL, B.Sc.

The note on absolute droughts during the period 1906–40, prepared during the war but not published until September 1947*, appeared immediately following one of the most widespread droughts on record. It is shown in *British Rainfall* 1947, that only 4 of the 82 representative stations selected to cover Great Britain and Northern Ireland failed to record an absolute drought between July 29 and September 16. This drought was sufficiently unprecedented, from a number of aspects, to warrant further investigation, and all the daily returns received by the British Rainfall Organization, Meteorological Office, have now been examined.

*GLASSPOOLE, J. and ROWSELL, H.; Absolute droughts and partial droughts over the British Isles, 1906–40. *Met. Mag. London*, **76**, 1947, p. 201.

[*To face p.* 260

Reproduced by courtesy of the Water Department, City of Birmingham

UP-STREAM FACE OF THE MAIN CABAN DAM, RHAYADER WATERWORKS

Reproduced by courtesy of the Leighton Buzzard Observer

SCENES OF HAVOC AT LINSLADE

Reproduced by courtesy of the Leighton Buzzard Observer

SCENES OF HAVOC AT LINSLADE

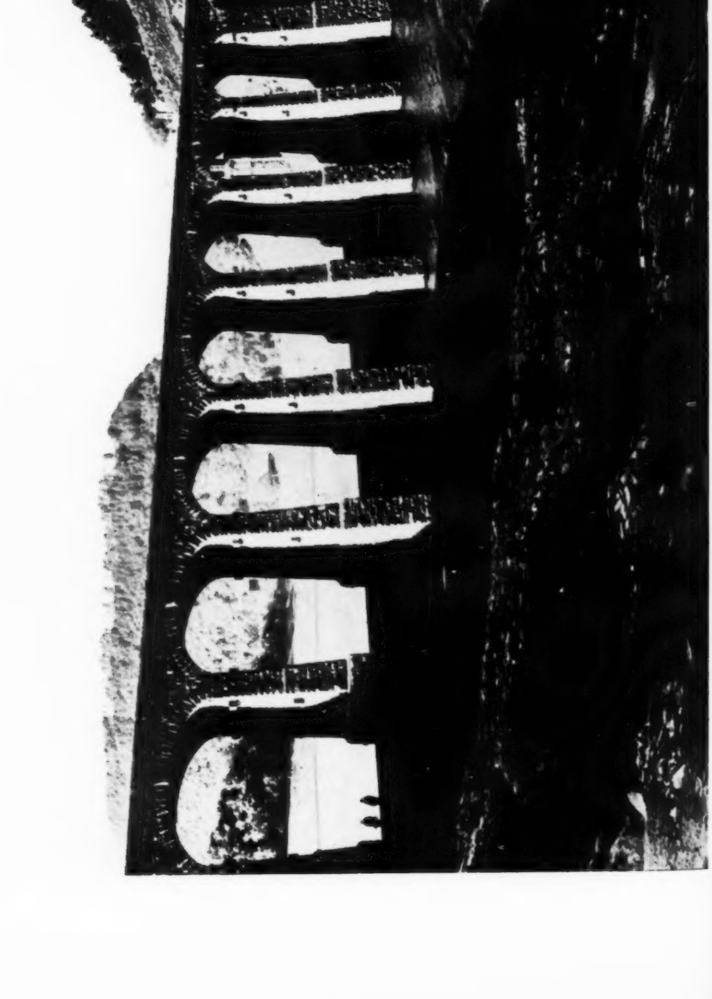
Reproduced by courtesy of Starr and Rignall, Ely

OVERTURNED BUS AT SUTTON, ELY

The bus fell on grass and only one headlamp and one window were damaged.

(see p. 247)

[*To face p.* 261]



Reproduced by courtesy of the Water Department, City of Birmingham

The map, Fig. 1, shows the greatest number of consecutive days without measurable rain within the period July 29–September 16. It will be seen that only small areas failed to record an absolute drought during this period. (An absolute drought is defined as a period of at least 15 consecutive days, to none of which is credited 0·01 in. of rain or more.) These areas were confined to the neighbourhood of Tavistock, central and north Wales, part of the Cheviots, the west of Co. Tyrone, Skye, the Isle of Lewis, Fortrose, Strathpeffer,

FIG. 1—GREATEST NUMBER OF CONSECUTIVE DAYS WITHOUT MEASURABLE RAIN, JULY 29–SEPTEMBER 16, 1947

Sutherland and the west coast of Ross. No other absolute drought on record covered so large a part of the country, even during the famous dry year of 1887, and the extent of the area with more than 30 days is also unprecedented.

Over a large part of the country, this period gave the longest absolute drought on record. This is particularly the case in northern England, as far south as Buxton, and also over much of Scotland, where the longest duration

previously recorded had rarely exceeded 25 days and only in isolated coastal districts had reached 30 days.

The longest droughts occurred at—

		days
Wye Agricultural College (Kent)	July 29–September 16	50
Wellingborough (Northamptonshire)	July 29–September 10	44
St. Neots (Huntingdonshire)	July 29–September 10	44
Woodhall Spa (Lincolnshire)	July 29–September 10	44

Only in the famous spring drought of 1893 has so long a period of absolute drought been recorded. Then the longest well authenticated, absolute droughts covered 60 days within the period March 4 and May 14, 1893, at Hastings, Winchelsea, Lewes and Haywards Heath.

A noteworthy feature of the August 1947 drought was the absence of measurable rain in the mountainous districts. Thus in the English Lake District at Borrowdale (the Moraine), Watendlath Farm and Keswick there was no measurable rain from August 3 to September 3 and hikers there must have found their mackintoshes an embarrassment.

The driest period over the country as a whole was August 7–31 (25 days), when the general rainfall over England and Wales, Scotland and Northern Ireland, only amounted to about 0·03, 0·04 and 0·09 in. respectively. This is the driest period over the whole area for which data are available. There was no rain over Northern Ireland during the eleven days August 10–20. In 1911, a year of frequent droughts, the driest periods over England and Wales were July 3–15 (13 days) with 0·013 in., January 26–February 9 (15 days) with 0·034 in. and June 1–11 (11 days) with 0·036 in.

The abnormal conditions justified an examination of all records to see if any days could be found without measurable rain at any station. No records of measurable rain were found at stations in Great Britain and Northern Ireland during the seven days August 13–14 and August 25–29. It is most unusual for any day to have no rain anywhere in the country.

The effects of the drought are illustrated by the two photographs (see photographs facing pp. 260 and 261), kindly made available by the City of Birmingham, Water Department. The first shows the up-stream face of the main Caban Dam, and the second a submerged dam farther up-stream with the Careg Ddu Viaduct. The photographs were taken on November 2, 1947, when the level of the Caban Reservoir was 68 ft. 6½ in. below top water level. The lowest level in 1947 in the Caban Reservoir was reached on November 9, when the level was 70 ft. 4½ in. below top water level. The normal water levels are easily discernable in the photographs. The storage capacity of the reservoir is 7,815 million gallons. The photographs give a good indication of the fine country in which the reservoir is situated, but the Caban Dam appears more impressive from the down-stream side, especially when the reservoir is overflowing, being 122 ft. high from stream bed to crest level and 610 ft. long.

METEOROLOGICAL RESEARCH COMMITTEE

The eleventh meeting of the Physical Sub-Committee of the Meteorological Research Committee was held at the Royal Aircraft Establishment, Farnborough, on June 22, 1950, by kind permission of the Director, R.A.E. Before the meeting members were shown the work of the Meteorological Research Flight.

The exceptional turbulence experienced by the De Havilland Comet aircraft on November 14, 1949, and the associated weather conditions were described in papers by Dr. G. S. Hislop, British European Airways, and Mr. J. K. Bannon, respectively; further investigations of jet-streams, regions liable to high-altitude turbulence, were discussed.

Temperature inhomogeneities in the free air, from a paper by Dr. R. Frith[1], were discussed and a paper on humidity in the upper troposphere and lower stratosphere[2], by Mr. J. K. Bannon, was noted.

A paper on the distance over which an aircraft might expect severe icing in certain weather conditions[3], by Mr. R. F. Jones, was received with interest. Diurnal variations of various weather elements over the ocean were also discussed.

The tenth meeting of the Synoptic and Dynamical Sub-Committee was held on July 19. The problem of the formation of radiation fog was discussed at length, emphasis being placed on the need for a better knowledge of the various physical processes involved and for a realisation of those factors which were important and those which may be neglected. The relevant part of the report on the observations made at various heights at Rye[4] was noted.

A report by Mr. F. H. Bushby[5] on Charney and Eliassen's one-dimensional numerical method for calculating motion of barotropic disturbances in a westerly airstream, was received with interest. The method, though very crude, is an attempt at numerical forecasting; possible improvements and alternative methods of attack were discussed.

---

[1]Met. Res. Pap., London, No. 552, 1950
[2]Met. Res. Pap., London, No. 563, 1950
[3]Met. Res. Pap., London, No. 564, 1950
[4]Met. Res. Pap., London, No. 546, 1950
[5]Met. Res. Pap., London, No. 556, 1950

OFFICIAL PUBLICATION

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 102—*Sandstorms on the northern coasts of Libya and Egypt.* By E. A. Lunson, B.A.

This note discusses the general weather conditions associated with khamsin depressions along the Mediterranean coast of Tripolitania, Libya and Egypt. Part I is a general discussion of these sandstorms—how they arise, how and where they are intensified and what effect they have on flying conditions. This concludes with a tentative classification into " good, moderate and poor " areas of districts between Tunis and the Canal Zone which are affected by these storms. In Part II the development and passage of a typical khamsin depression is traced from Malta to the Suez Canal.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society on June 21, 1950, with the President, Sir Robert Watson-Watt, F.R.S., in the Chair, Mr. H. H. Lamb presented a paper entitled " Types and spells of weather around the year in the British Isles: annual trends, seasonal structure of the year, singularities ".

Mr. Lamb said his work was based mainly on a classification of daily weather maps of the north-east Atlantic, for the fifty years 1898-1947, made by Capt.

Levick, R.E., and presented by him to the Forecasting Research Division. The maps were classified into seven types: anticyclonic (anticyclones over or near the British Isles), cyclonic (depressions over or frequently passing over the British Isles), westerly, north-westerly, northerly, easterly and southerly. Less than 1 per cent. of the maps were unclassified.

From this classification the outstandingly long spells of weather, lasting over 25 days, had been picked out. Mr. Lamb showed frequency curves of the occurrence of these long spells and of the occurrence of each of the seven defined types on every day of the year. Among the many interesting facts revealed by these curves were: long spells of all types are most frequent from the middle of July to the middle of August and from late September to early November and least frequent in early September and from April to June; anticyclonic spells are most frequent in early October; cyclonic spells in July–August and in October; westerly spells in December–January; north-westerly spells in July; northerly spells in April–May; easterly spells in February–March and in October. Westerly spells are decidedly infrequent in May and easterly and southerly ones in the middle of summer. Westerly spells have a higher frequency, over 20 per cent., around the turn of the year than any other type at any season. Southerly spells are infrequent at all times.

Turning to the frequency of types on individual days a brief summary of the findings is: anticyclonic type, most frequent in summer and early autumn and least in late October; westerly type, the most frequent of all types with maximum frequency in early January and late August and minimum in May; north-westerly, little annual variation; northerly, most frequent in April and May and least from early December to early February; easterly, most frequent in late April to early May and late autumn and very markedly infrequent in high summer; southerly, little annual variation but least frequent in summer; cyclonic, most frequent in late July and August and again in October and least in early to mid September.

From these results Mr. Lamb suggested a division of the year into the five periods or natural seasons of:—

High summer, June 18 to September 9.

Autumn, September 12 to November 19.

Forewinter, November 20 to January 19.

Late winter or early spring, January 20 to March 29.

Spring or early summer, March 30 to June 17.

Mr. Lamb then described the short-period recurrences of weather types known as "singularities" revealed in the classification. He described 21 of these. Some of them such as the cold spells of early May, the anticyclonic foggy weather of late November, the "Indian summer" anticyclones of late September, and the late autumn rains of October are well known.

To the forecaster, Mr. Lamb pointed out, the work was of value as a general guide, particularly at times when a long spell is becoming established and is threatened with breakdown. The outlook could on such occasions be judged in the light of the historical trends of the stability of long spells of the particular type at the particular time of the year.

Mr. Gold, speaking in the discussion, considered that a more detailed classification, such as he had given in *Geophysical Memoirs* No. 16, was needed for

the use of analogues in forecasting, and that it would be better to give the mid points of spells instead of the less definite beginning and end, and that in the north-easterly type the sunshine over quite a small area in southern England varied considerably. Dr. Crowe, referring to the relation between weather type and rainfall records, said that rainfall regimes cannot be related to the pressure type over such a big area as Great Britain, and also suggested that singularities can vary with the particular 50 years considered.

Dr. Tor Bergeron, Professor of Meteorology at Uppsala University and Symons Medallist, lectured to the Society on the evening of June 28, 1950, on the subject of "Tropical hurricanes".

Dr. Bergeron referred, in opening his lecture, to the old theories of the formation of these storms, namely Ferrel's convective and Dove's kinetic hypotheses. He said his own interest in them commenced about 1928 when he considered the probable factors for their formation were an unstable atmosphere and a pre-existing low on the intertropical front. This view was supported by the absence of such storms in the tropical South Atlantic and south-east Pacific where the intertropical front was never found.

Now recently Palmén had studied the environment curves of air over the Caribbean Sea and shown that, whereas in September there was convective energy available at all levels to 300 mb., in February, though there was an over-all small positive balance for convection to 300 mb., the convective energy was negative in the lower layers. Dr. Bergeron showed charts of the areas of sea temperatures exceeding 80–81°F. in September and March which outside a 10° belt on the equator and the tropical South Atlantic corresponded well with the charts of areas of formation of tropical storms. The storms cannot form within 5° of the equator because of insufficiently strong Coriolis acceleration.

Dr. Bergeron then linked the formation of tropical storms with recent work done partly by the United States Thunderstorm Project on the structure of cumulonimbus clouds. It had been shown by Riehl and others that the rain of thunderstorms over land produced by evaporation and cooling of the surface a cold low-level "high-pressure" area which effectively prevented a gigantic convective development in Ferrel's manner such as took place in the tropical storm. Over the tropical sea the surface temperatures were much less affected by the rain, but nevertheless every thunderstorm did not develop into a tropical storm, and the explanation was that, as Riehl had shown, a pre-cursory low was necessary. This pre-cursory low provided the necessary convergence in the initial stages to overcome the effect of the tendency to high pressure at the surface.

The tropical storm of September 17, 1947, passing over the narrow Florida peninsula from the Atlantic to the Gulf of Mexico, was described to show that the main rainfall was symmetrical in a ring about the centre and outside the area of maximum wind. The down-current produced by the rain assisted the storm circulation in the vertical plane caused primarily by the temperature structure (acceleration due to the isobaric-isosteric solenoids). The storm of October 14–16, 1947, which came inland over South Carolina was also described to show how a tropical storm soon began to die under the influence of the surface "cold high" as it came overland. The central pressure of this storm rose

from 975 to 1000 mb. in 30 hr., but the degenerating cloud system was carried on to Chicago.

Dr. Bergeron also gave some illustrations of "tropical storm" formations in temperate zones such as the cyclone of July 9, 1929, over the Baltic.

LETTERS TO THE EDITOR

Cloud phenomenon near Ferring, Sussex, May 14, 1950

At 1600 B.S.T. on May 14, 1950, I noticed from Ferring, near Worthing, Sussex, a small white cloud in an otherwise quite clear sky, which had a definite spiral pattern, as in the sketch below. It remained visible for about twenty minutes,

gradually fading and the upper part shearing to the left. It was travelling very slowly from the south. It reminded me somewhat of a small poorly developed Contessa del Vento and was probably due to a local whirl in the free air.

C. E. P. BROOKS

June 1950

[The Larkhill and Downham Market ascents for 1500 G.M.T. on May 14 show that the wind was NE. in the lowest levels steadily backing and becoming NW. at about 300 mb. (30,500 ft.). From 40,000 to 50,000 ft. the wind was westerly. The air was extremely dry at all levels up to the limit of the humidity observations at 350 mb.—Ed. *M.M.*]

Altocumulus castellatus clouds

Mr. R. H. Eldridge, in his letter in the June number of the *Meteorological Magazine,* raises a difficult and important point in cloud classification. He is undoubtedly right in his main point, namely that the tops of typical altocumulus castellatus clouds consist of small turrets, nearly always in a group or along a belt, with each turret formed originally from an ordinary altocumulus cell. The parent layer has frequently a fairly normal appearance for an appreciable time, but the cells grow thicker and then erupt upwards, sometimes quite suddenly, as is well shown on one of the German cloud films. If the small cells amalgamate into large agglomerations with domed tops they should be called cumulus congestus. Frequently they soon become cumulonimbus, and this had already happened in the case of the cloud depicted in the photograph in the issue of December 1949, since fibrous structure is visible. The freezing level was at 12,500 ft., so that the top of the cloud almost certainly exceeded 20,000 ft. It was much farther away than the cloud in the foreground with a base at about 8,000–10,000 ft. It is interesting to note that this foreground cloud shows no

turrets, but nevertheless there is no reason to doubt that it was the parent layer of the cumulonimbus. This cannot be deduced with complete certainty from the photograph, but the observed atmospheric structure on that day supplies strong additional evidence for it. Thunder and lightning could have accompanied this cumulonimbus column. There are many cases on record of thunderstorms in the British Isles with the main cloud base at 10,000 ft. if not higher. The one on August 24, 1944, gave over an inch of rain over quite a large area (see *Meteorological Magazine* for November 1949, p. 309). In a dry climate, like that of the Mediterranean in summer, high-based thunderstorms are of course more frequent, and the base probably sometimes exceeds 15,000 ft.

A similar type of cloud with a sharply defined edge should always be called cumulus congestus. The current edition of the " International Cloud Atlas " was published as far back as 1932. It remains a very valuable publication, but it does not give adequate guidance on the point under discussion. Its Plate 55 shows an example of what is called stratocumulus castellatus, and this certainly exists in the foreground of the picture, but the dominant clouds are large cumulus, and the illustration is therefore misleading, and more especially the caption under the photograph. The picture itself is of exceptional interest. The nearest clouds in that photograph illustrate the true castellatus form, but in the larger clouds farther away the small turrets have amalgamated into larger agglomerations. In such cases the cell structure at the cloud base often remains much as before, apart from a general darkening. Many examples of altocumulus opacus and some of stratocumulus opacus have cumulus tops which are invisible from the ground. An observer can only report what he sees, but it is worth while to keep a good look-out for the castellatus form and for the tops of large cumulus or cumulonimbus in such conditions, if there are any gaps in the cloud sheet.

A new edition of the " International Cloud Atlas " is in course of preparation, and a committee formed by the International Meteorological Organization for this purpose has already had two meetings at Paris. All the difficult problems have had a very full discussion, and every effort is being made to give clear and definite guidance to observers. It is in a few cases necessary to lay down rather arbitrary distinctions which have the nature of conventions framed with the object of securing the maximum attainable uniformity among observers. Complete standardization is impossible, since nature shows infinite gradations in the structure and appearance of clouds, and also a very large number of transformations, so that marginal categories are unavoidable, but at least the situation will be improved.

C. K. M. DOUGLAS

July 5, 1950

NOTES AND NEWS

Whirlwind near Walsrode, Germany

At 1800 G.M.T. on April 26, 1950, a depression of central pressure 993 mb., was centred over Holland. A cold front which extended to the Frisian Islands. thence south-eastwards, was moving in a north-easterly direction at about 30 kt. over north-west Germany and there was a marked trough of low pressure along the front. In the Buckeburg-Bad Eilsen area, the frontal passage was associated with gusts reaching 55–60 kt., a rise of pressure of 2–3 mb. and a fall of temperature from 52°F. to 36°F. The freezing level over Hanover fell from 4,500 ft.

to 2,000–2,500 ft. during the time between successive upper air ascents made at 1400 and 2000.

A report on " Unusual Weather " on April 26 was received from a British Army unit in the Walsrode area (52°50′N. 09°30′E.). This report reads as follows:—

". . . At approx. 1825 hours a gust of wind of great force suddenly sprang up and blew for about 30 seconds bending trees right over. This was followed by a dead calm for approx. 1 minute during which time the sky grew dark. The wind blew up again rather like a whirlwind. It confined itself to an area of approx. 200 sq. yards and lasted for approx. 45 seconds. The strength of the wind was such that it sounded like the shrill whine of a missile travelling at high speed and the noise was heard 8 kilometres away.

The ' whirlwind ' effect moved within the 200 sq. yards during which time it uprooted four very large trees, half uplifted several others, lifted the roof off a shed, blew windows in, took off the tiles and large areas of roofing from several buildings. A fire bell weighing ½ cwt., suspended by an iron chain from the branch of a large tree, and which appeared to be caught by the ' fringe ' of the whirlwind, was blown into a horizontal position for quite a number of seconds.

The duration of the whole incident was approx. 2½ minutes, after which time the weather returned to normal."

It has since been ascertained from the army unit that the phenomenon which appeared to form over the area was not accompanied by any heavy rain or hail. Observers were not clear as to whether a funnel extended downwards from the base of the cloud but they were well aware of a definite whirlwind circulation which sucked up such a considerable amount of dust and debris that the adjacent fire piquet thought it was a column of smoke and reported a possible fire.

REVIEWS

The Thunderstorm—Report of the Thunderstorm Project. United States Weather Bureau. 10 in.×7½ in., pp. ix.+287, *Illus.* Washington D.C. 1949. $2.25.

The United States Thunderstorm Project was probably the most elaborate single meteorological investigation ever made.

The United States Government agencies concerned—Air Force, Navy, National Advisory Committee for Aeronautics, and Weather Bureau—did not keep the results to themselves until a comprehensive report could be prepared, but published for the information of all the world valuable reports and papers during the progress of the investigation. Now we have the eagerly awaited report on the whole Project. The opening paragraph of the preface describes the Report in the following words: " This publication is to be considered as the final report of the present phase of the Thunderstorm Project. All the research possibilities suggested by the data obtained on the Project have not been explored. Only the more obvious results are presented herewith, but it is expected that some of the participants in the analysis and other meteorologists will use the abundant material to glean additional knowledge of thunderstorms."

The Report opens with an introduction of 13 pages which gives the history of the Project, the plan of observations, description of the areas of operations and

[To face p. 268

Reproduced by courtesy of F. Greenaway

HAILSTONES AT NORTH CRAWLEY, NEAR NEWPORT PAGNELL, BUCKS
(Actual size)
(see p. 247)

To face p. 269]

Reproduced by courtesy of D. Wigmore

THREE-LEGGED RACE AT THE HARROW METEOROLOGICAL OFFICE SPORTS MEETING, JULY 26, 1950

a statement of the number of storms investigated, number of aircraft flights into storms and so forth. The main Report, occupying 237 pages consists of three parts, entitled description of the thunderstorm, flight operations in thunderstorm conditions and examples. Part 1 is divided into eight chapters dealing with thunderstorm structure and circulation, turbulence and hydrometeors within the thunderstorm, thunderstorm weather near the surface, electric fields inside the thunderstorm, the thunderstorm as disclosed by radar, effect of environment wind field on existing thunderstorms, preferred areas of thunderstorm development, and squall lines. The main reason for the Project was the necessity for accurate information on flight in thunderstorms. This information is provided in Part 2, " Flight operations in thunderstorm conditions ". To many meteorologists, Part 3, which contains very detailed reports and observational data on five thunderstorms, will probably prove the most interesting part of the book in providing material for study. Finally, there are a bibliography, five appendices describing the instruments, and an index.

The Project used two areas, one near Orlando, Florida, where thunderstorms are nearly all of the air-mass type, and another in Ohio where frontal storms occur as well. The surface stations were equipped with autographic instruments; there were 55 such stations spaced about one mile apart in Florida and the same number spaced about two miles apart in Ohio. Upper air temperatures and humidities were measured by both radio-sondes and aircraft, and upper winds by the radar-wind method and by radio direction-finding on the radio-sondes. Aircraft flights were made to measure vertical motions, horizontal and vertical temperature distribution and the electric field; generally five aircraft spaced at intervals up to 25,000 ft. flew through storms. A vast amount of information on thunderstorm structure is now available from this dense network of stations and observations by specially trained aviators and specially fitted aircraft.

The general picture of the development of air-mass storms which emerges is briefly as follows: the predominant feature of the cumulus stage of development is the up-draught. No radar echo appears until the top of the cloud reaches above the freezing level. The rising column of air is shown to entrain air as it ascends and the mixing of the rising air with the air of the environment is of great importance. Rain first appears several thousand feet above the freezing level and higher up there is a gradual transition to dry snow. During this development stage the thunderstorm cell which is initially about two miles wide grows to a width of about six miles. The fall of rain at the surface marks the transition from the cumulus to the cumulonimbus, and from then onwards the region originally occupied by an up-draught contains a down-draught produced by the rain. The up-draught is found in a region adjacent to the down-draught and in the mature storm may have a speed in places of 100 ft./sec. The down-draught spreads out in the lowest layers of the atmosphere and is cooled by the evaporating rain. This spreading out of the cool down-draught air cuts off the supply of warm air to the up-draught so that the storm dissipates. It may, however, in turn stimulate the ascent of adjacent masses of warm air and so lead to the formation of more thunderstorms.

The description is substantiated in detail by charts of convergence and divergence and short-period rainfall measurements. Tables and figures give the frequency distributions of the velocities and widths of the up and down currents.

For specifying the intensity of the turbulence in the storm as found from accelerometer recordings made on the aircraft, use is made of the "effective gust velocity" concept which represents the speed of a "sharp-edged gust" that would give the same acceleration as that actually experienced. The maximum effective gust velocities encountered were of the order of 40 ft. per sec. but only a small proportion exceeded 20 ft. per sec. The most frequent horizontal distance over which the changing wind speed giving the gust occurred was 150 ft.

Heavy icing was encountered infrequently and on no occasion made safe flight impossible by the P-61C aircraft employed but this lack of serious icing is ascribed to the aircraft not being sufficiently long in the cloud.

Although the initial stimulus to the Project was the promotion of the safety of flight this matter, important though it is, does not dominate the Report, and no one can say that the purely scientific side has been neglected. Thus detailed measurements were made of the electric field and these are correlated with the up and down currents. Further, the pressure variations at the surface are studied in detail.

This Report must now be considered the prime source of information on thunderstorm structure. Bound in buckram and printed on art paper it is produced in a manner worthy of the work described. G. A. BULL

On the formation of drops in clouds and fog. By R. R. Vierhout. Koninklijk Nederlandsch Meteorologisch Instituut No. 102. Mededeelingen en Verhandelingen Serie B, **2**, No. 12. 12¼ in. × 8¾ in., pp. 20. 's. Gravenhage, 1948. 2·50 florins.

The author first discusses the rate of evaporation of an isolated drop on the basis of the rate of diffusion of water-vapour molecules in air and the kinetic theory of gases and following Fuchs in the general treatment. The effect of neighbouring drops on this evaporation rate is next examined and the time computed for complete evaporation of drops of various sizes in a cloud with dimensions of the order of a few hundred metres and one hundred per cent. relative humidity. The results indicate that a drop of radius 10 microns has a life of about 45 minutes, but that if the order of magnitude of the drop radius is decreased or increased the life of the drop is measured in seconds or days respectively. Somewhat similar results are obtained for the time of growth of a drop in a supersaturation of a few tenths per cent. The author next considers growth of drops by coalescence, resulting from larger drops overtaking smaller drops while falling under the influence of gravity, and obtain, numerical results indicating that a cloud thickness of about 1,300 m. is necessary for drops to grow to a radius of 1 mm. by coalescence. Finally the author considers the forces between two drops due to condensation and evaporation, and shows that these forces are very much greater than the electric forces between two singly charged ions unless the drop radius is a fraction of a micron.

It is odd that in a memoir with this title the influence of the nucleus of condensation in lowering the vapour pressure over the drop receives only a cursory mention and is not taken into account in the computations. It is surprising also to find Stokes' law assumed to hold for the terminal velocity of drops with radius up to 1 mm. Assumptions such as these may not invalidate the general character of the results but must seriously affect the actual numerical

values obtained. In short, the physical basis of the work has received less attention than the mathematical superstructure. It seems desirable also to register a protest against the use of the word " drizzle " to describe drops having a diameter of 2 mm.

The memoir is unnecessarily difficult to read as a result of the almost complete absence of sectional headings.

A. C. BEST

Meteorology for Seamen. By Cdr. C. R. Burgess, O.B.E., R.N. $8\frac{1}{2}$ in. $\times$ $5\frac{1}{2}$ in. pp. xi+252. *Illus.* Brown, Son and Ferguson, Ltd., Glasgow. 1950. 15*s.*

The seaman will find plenty of useful information in this concise and attractive book on marine meteorology. It is divided into four parts: I—" Factors which go to make up the Weather ", II—" The Climate of the Oceans ", III—" Weather Forecasting ", IV—" Observing and Recording the Weather ". There are plenty of good clear diagrams, many excellent and unusual photographs, as well as some clearly drawn examples of weather charts.

The book is evidently not intended for cramming for examinations; no attempt is made to " blind the reader with science ", but it is suitable for general reading on the subject, without expert knowledge. The author might easily have given it the sub-title "A practical meteorological guide for seamen", for this is what it is.

Written by a seaman for seamen it is full of helpful hints, which are not always found in books on this subject, and which may well be of value to the seaman who cares to apply weather knowledge for the safety or economical operation of his ship. This particularly applies to the chapter on " Fog, Mist and Haze " (probably the mariner's greatest enemy), and that on " Weather Forecasting by Seamen ". For example, in the former chapter it is pointed out how and why visibility improves down-wind in Arctic sea-smoke, and up-wind, *i.e.* towards warmer water, in the case of sea fog; also that early morning is sometimes unsuitable for making a landfall when there is a liability of radiation fog. The paragraphs on forecasting sea fog, by the use of the wet- and dry-bulb and sea temperature observations, are interesting, and should prove helpful in waters where this is likely to occur; as is also the suggestion that foggy areas can be avoided, in some cases, with the help of isotherm charts in conjunction with the above readings. Chapters 20 and 21 give guidance to the mariner on the subject of forecasting his weather by using the information contained in weather bulletins for shipping. The use of baratics and synoptic information in drawing up a weather chart in the simplest and most time-saving manner, so as to give a more localised picture of the weather than that which can be given in ocean forecasts, is discussed in detail. If this guidance is followed, a shipmaster might, in certain cases, be able to use weather information to his advantage, by avoiding areas of unfavourable weather; thus by an alteration of course and/or speed a better passage might be made, with less liability of damage. Chapter 21, " Watch your own Weather ", points out that one should not rely implicitly on official forecasts when out in the middle of an ocean, but should always be on the look out for " on the spot " changes of pressure, wind and weather. Portents of the sky and sea, used by seamen throughout the centuries, are interestingly discussed in the light of modern knowledge.

The formation, movements and meetings of the various types of air masses, and the subsequent effects thereof, are dealt with in a straightforward manner. The remarks on general phenomena are illuminating and call the attention of the reader to wonders of nature, which will give added interest to any voyage.

Notes on "Radar and Weather" deal not only with various meteorological effects upon the performance of this aid to navigation, but also the meteorological uses to which radar can be put.

There are a few points which merit criticism; on p. 62 in the paragraph dealing with the position and shape of the new moon, it is stated: "only in autumn does it lie with its horns pointing downwards in middle latitudes"; this aspect can never be seen after sunset in any latitude, and can only be seen in daylight when the sun's altitude is greater than that of the moon's. In Chapter 15, dealing with tropical revolving storms, no mention is made of the necessity of stopping the ship in order to ascertain whether the wind is backing or veering, in relation to the storm area passing over the ship at that place. In Chapter 20, "Weather Forecasting by Seamen", the statement on p. 148 that it takes two hours to plot a weather map for the eastern North Atlantic may perhaps frighten some mariners, but the author seems to be referring to a full synoptic chart, and not to the Atlantic Weather Bulletin which can, with practice, be plotted in about an hour.

These items, however, do not detract from the value of this book. To have written on such a large and complex subject as modern marine meteorology, to have kept it within a reasonable size and price, and yet to have touched on all that the mariner needs, is no mean achievement. This book will be a useful addition to a ship's officers' library.

R. REID

OBITUARY

Arthur Charles Marsh.—We regret to record the death on April 22, 1950, of Mr. Arthur Marsh of 113, Poole Road, Bournemouth, a Fellow of the Royal Meteorological Society since 1920 and Meteorologist to the Bournemouth Corporation since 1937. When Mr. Marsh returned from the first world war, he became deputy to his father-in-law Charles Dales (Bournemouth's first official Observer who was appointed in 1920). As Mr. Dales advanced in years they reversed their roles, and from 1937 onwards Mr. Marsh was the Observer while Mr. Dales served as Deputy until his death at the age of 93 in 1945.

We note with pleasure that Mr. Dennis Bernard Marsh has been appointed as Meteorological Registrar in succession to his father so that the long and useful records from Bournemouth have great prospect of being well maintained.

P. R. ZEALLEY

We regret to report the death of Mr. H. N. Warren, Director of the Australian Commonwealth Meteorological Service, which occurred at Adelaide on August 5, 1950.

METEOROLOGICAL OFFICE NEWS

Bird watching from an ocean weather ship.—During the summer months three ornithologists, members of the British Trust for Ornithology, are sailing aboard the ocean weather ships, for one voyage each, to make observations of the movements of sea birds and study bird migration.

Air Day in B.A.F.O.—Several thousand spectators, mostly Belgian, British, Danish and Norwegian troops, visited the meteorological stand in the exhibition prepared for B.A.F.O. Air Day, held at Gütersloh airfield on June 20, 1950.

The making and collection of observations, and the preparation and analysis of weather charts were demonstrated, and the diverse uses of weather forecasts illustrated. The meteorological instruments exhibited included a sectioned working model of a radio-sonde, a radio-sonde balloon prepared for release, and a facsimile machine reproducing simple synoptic charts.

Marine exhibition.—At the close of the "Science of Weather" exhibition at the Science Museum, South Kensington, mentioned in the June number, the exhibits prepared by the Marine Branch were transferred to H.M.S. *Wellington*, Headquarters Ship of the Honourable Company of Master Mariners, lying off the Embankment, London, for show to the Company's members during the month of July.

High pilot balloon ascent.—A 90-in. pilot balloon with a free lift adjusted to give a rate of ascent of 500 ft./min. was followed for 2 hr. 10 min. at Ronaldsway on May 13, 1950. If the rate of ascent of 500 ft./min. were realised throughout the flight of the balloon, the height reached would be 65,000 ft. On the same assumption the distance from theodolite to balloon when last seen was approximately 60 mi.

Academic success.—The University of Durham has conferred the degree of Doctor of Science upon Mr. F. Pasquill. We offer him our congratulations.

Amateur radio transmissions.—Staff interested in amateur radio are invited to look for station VS9AA operated on the 7, 14 and 28 Mc. Amateur Bands by Mr. S. G. Abbott (Experimental Officer) in the Meteorological Office, Royal Air Force, Khormaksar, Aden. Reports on the quality of reception will be welcomed by Mr. Abbott.

Sports and Athletics

Harrow.—The first annual athletics meeting of the Harrow Meteorological Office Social and Sports Club was held at Alperton Recreation Ground on July 26, and proved an outstanding success. A feature of the meeting was the inauguration of Meteorological Office championship events. The winners of the championship events were D. J. Mannion, Hendon (100 yards), W. Lawson, Leeming (half mile), Miss M. K. Hunt, London Airport (ladies' 100 yards), Central Forecasting Office (mens' relay) and Harrow Office (ladies' relay). The meeting ended very happily with the presentation of medals and certificates by Mrs. J. M. Stagg.

London Airport.—The meteorological office staff at London Airport had a successful day at the first Annual International Sports at the Airport on July 15, 1950. The team of nine gained 10 cups and 4 plaques besides other awards and succeeded also in winning the Bristol Challenge Cup. This handsome trophy was presented by the Bristol Aeroplane Company as a token of their appreciation of services rendered, when the Brabazon visited the airport in June, to be awarded annually to the Operating Company or Airport Department scoring the highest aggregate points during the meeting. The meteorological office scored 89 points, the runners up being H.M. Customs (Landing) with 77 points.

We would offer congratulations to:—

Miss B. Edwards, on winning the Air Ministry Ladies' Tennis Singles Championship for 1950.

Miss N. Edwards and Mr. P. J. Meade on reaching the semi-finals of the mixed doubles of the Air Ministry Tennis Tournament.

Mr. H. G. Stannard on winning the Kingston Prize of the Surrey Rifle Club, with 32 points out of 35.

Corporal E. W. Heasman on winning the mile event at the athletics meeting between Air Ministry Harriers and the Board of Trade held on June 19, 1950.

L.A.C. T. D. Abbott on being selected to compete in the International Services Swimming trials at Aldershot on July 13, 1950.

Horticultural Show.—We would offer congratulations to Mr. B. G. Brame on the award to him of the Banksian Medal for his exhibits at the annual show of the Air Ministry and Ministry of Civil Aviation Horticultural Society held on July 11, 1950. The Banksian is a memorial medal presented by the Royal Horticultural Society to each Society for the competitor gaining most prizes at its annual show.

WEATHER OF JULY 1950

Mean pressure was above 1020 mb. from around the Azores westwards nearly to Bermuda, and above 1015 mb. in the northern half of Greenland and for a considerable distance over the sea to the eastward; in the latter region it was 5–8 mb. above the July normal. The mean was below 1005 mb. immediately to the south of Iceland, being 5–10 mb. below the July normal in that region, which formed part of a much larger area throughout which pressure was below normal, but by a smaller amount. This area extended southwards and south-westwards at least to latitude 30°N. and south-eastwards to include central, southern and western Europe, most of the Mediterranean and the extreme north of Africa. In North America pressure was generally within 1 or 2 mb. of normal.

In the British Isles the weather was mainly unsettled; it was very wet over much of the southern half of England and Wales, in Northern Ireland and west and central Scotland. Sunshine considerably exceeded the average in Scotland, particularly in the north, but totals were less than the average in Northern Ireland and locally in England.

A small anticyclone gave mainly fair weather in the opening days but a trough of low pressure over France caused thunderstorms in south-east England during the night of the 2nd–3rd. On the 3rd a depression over Brittany moved to north-west Germany and further rain, heavy locally, occurred in southern and eastern districts of England. On the 5th another disturbance moved from north-west France to northern Germany and, on the 6th, a shallow depression off the south of Ireland moved to the southern North Sea; rain and local thunderstorms occurred chiefly in southern England and Ireland (2·32 in. at Lansdown, near Bath, on the 6th). The period 3rd to 6th was dull in England and Wales but sunny in the north of Scotland.

From the 7th to 9th a depression was situated on the Atlantic westward of the British Isles; on the 7th and 8th troughs associated with this system caused rain in Scotland and Ireland. On the 9th a shallow trough moved across England; heavy rain and local thunderstorms occurred in the south-east and east in the evening and during the following night (2·14 in. at Odsey, south-west

Cambridgeshire). Temperature rose considerably and the 9th was the warmest day of the month at most places in England; maxima of 80°F. or above were registered at a number of places in the eastern half of the country and temperature reached 85°F. at Mildenhall, near Newmarket. On the 10th and 11th a secondary depression moved east-north-east across Ireland and northern England causing further rain. On the following day a ridge of high pressure, moving east, was associated with fair weather in eastern districts though rain occurred in the west and north. Unsettled weather was renewed on the 13th, when a depression off the west of Ireland moved irregularly north-east and later turned north; rain fell generally on the 13th and, in the west and north, also on the 14th (3·97 in. at Loch Sloy Dam near Loch Lomond on the 13th). From the 15th to 18th a deep depression westward of Ireland moved slowly north-east and brought rain generally on the 15th and showers and local thunderstorms on the 16th and 17th. Rainfall was heavy locally during this spell; for example, 2·08 in. at Llyn Fawr, Glamorganshire, and 2·07 in. at Treherbert, Glamorganshire, on the 16th, 2·23 in. at Onich, Inverness-shire, and 2·10 in. at Fort William on the 17th and 2·26 in. at Blaenau Festiniog, Merioneth, on the 18th. By the 19th an anticyclone over France had intensified, while a trough off south-west Ireland moved north-east. Temperature rose temporarily and fair weather occurred over most of England but rain fell in the west and north; temperature reached 79°F. at Felixstowe and 77°F. at Gorleston and London Airport. A further period of unsettled weather ensued; from the 21st to 23rd an Atlantic depression westward of Scotland moved slowly north. Associated troughs moving slowly east caused showers and local thunderstorms on the 21st, and a secondary depression moved east-north-east across Ireland and northern England to the north of Denmark on the 22nd and 23rd and was associated with more rain and local thunderstorms (2·14 in. at Sheepstor, south Devon, on the 22nd). Thereafter, small wave depressions to the south of England moved east; some rain occurred in the south of England and there were scattered showers in Scotland and Ireland.

Subsequently, an anticyclone off our south-west coasts moved east-north-east to Germany, while a depression off south-east Iceland moved west-south-west. Fair weather prevailed in England from the 26th to 29th, apart from local thunderstorms on the 28th. Troughs of low pressure caused showers in Scotland and Ireland and local thunderstorms occurred in Scotland on the 26th and 27th. On the 30th a trough of low pressure to a depression south of Iceland, moving east, caused some rain in all districts.

The general character of the weather is shown by the following provisional figures:—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales	86	39	+0·4	139	+2	100
Scotland	74	32	+0·6	133	+4	113
Northern Ireland ..	71	42	+0·1	191	+7	92

RAINFALL OF JULY 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square	3·16	133	*Glam.*	Cardiff, Penylan	5·17	168
Kent	Folkestone, Cherry Gdn.	2·98	142	*Pemb.*	St. Ann's Head	2·64	102
,,	Edenbridge, Falconhurst	2·74	119	*Card.*	Aberystwyth	4·30	141
Sussex	Compton, Compton Ho.	4·22	149	*Radnor*	Tyrmynydd	4·68	114
,,	Worthing, Beach Ho.Pk.	2·75	135	*Mont.*	Lake Vyrnwy	6·22	175
Hants	Ventnor, Roy. Nat. Hos.	4·36	216	*Mer.*	Blaenau Festiniog	9·08	107
,,	Bournemouth	4·29	201	*Carn.*	Llandudno	1·48	66
,,	Sherborne St. John	4·83	217	*Angl.*	Llanerchymedd	2·38	83
Herts.	Royston, Therfield Rec.	5·68	225	*I. Man.*	Douglas, Borough Cem.	3·05	100
Bucks.	Slough, Upton	4·12	215	*Wigtown*	Port William, Monreith	3·06	109
Oxford	Oxford, Radcliffe	5·33	225	*Dumf.*	Dumfries, Crichton R.I.	4·30	131
N'hant.	Wellingboro', Swanspool	3·30	144	,,	Eskdalemuir Obsy.	6·01	147
Essex	Shoeburyness	2·09	114	*Roxb.*	Kelso, Floors	2·39	91
,,	Dovercourt	2·46	123	*Peebles*	Stobo Castle	3·73	129
Suffolk	Lowestoft Sec. School	2·55	112	*Berwick*	Marchmont House	2·71	89
,,	Bury St. Ed., Westley H.	2·89	116	*E. Loth.*	North Berwick Res.	2·76	107
Norfolk	Sandringham Ho. Gdns.	3·63	142	*Midl'n.*	Edinburgh, Blackf'd. H.	3·11	110
Wilts.	Bishops Cannings	5·41	217	*Lanark*	Hamilton W. W., T'nhill	4·37	152
Dorset	Creech Grange	6·82	278	*Ayr*	Colmonell, Knockdolian	3·43	109
,,	Beaminster, East St.	5·22	201	,,	Glen Afton, Ayr San	5·38	128
Devon	Teignmouth, Den Gdns.	4·07	175	*Bute*	Rothesay, Ardencraig	6·40	162
,,	Cullompton	5·49	204	*Argyll*	L. Sunart, Glenborrodale		
,,	Ilfracombe	3·36	132	,,	Poltalloch		
,,	Okehampton, Uplands	5·40	167	,,	Inveraray Castle	8·63	173
Cornwall	Bude, School House	2·93	120	,,	Islay, Eallabus	6·75	198
,,	Penzance, Morrab Gdns.	3·88	143	,,	Tiree	6·91	191
,,	St. Austell	4·43	132	*Kinross*	Loch Leven Sluice	4·82	167
,,	Scilly, Tresco Abbey	3·36	151	*Fife*	Leuchars Airfield	3·37	130
Glos.	Cirencester	3·75	145	*Perth*	Loch Dhu	10·12	210
Salop.	Church Stretton	3·08	117	,,	Crieff, Strathearn Hyd.	4·95	167
,,	Cheswardine Hall	2·66	98	,,	Pitlochry, Fincastle	4·74	176
Worcs.	Malvern, Free Library	3·16	139	*Angus*	Montrose, Sunnyside	3·83	146
Warwick	Birmingham, Edgbaston	2·95	127	*Aberd.*	Braemar	4·26	166
Leics.	Thornton Reservoir	2·26	91	,,	Dyce, Craibstone	4·43	146
Lincs.	Boston, Skirbeck	2·66	121	,,	Fyvie Castle	3·94	121
,,	Skegness, Marine Gdns.	3·69	169	*Moray*	Gordon Castle	2·79	87
Notts.	Mansfield, Carr Bank	1·76	67	*Nairn*	Nairn, Achareidh	2·17	85
Derby	Buxton, Terrace Slopes	3·45	88	*Inverness*	Loch Ness, Garthbeg	2·91	120
Ches.	Bidston Observatory	1·94	75	,,	Glenquoich	7·40	115
Lancs.	Manchester, Whit. Park	3·14	95	,,	Fort William, Teviot	7·96	163
,,	Stonyhurst College	4·38	113	,,	Skye, Duntuilm	3·74	100
,,	Squires Gate	2·74	99	*R. & C.*	Tain, Tarlogie House	3·47	127
Yorks.	Wakefield, Clarence Pk.	1·64	65	,,	Inverbroom, Glackour	2·78	75
,,	Hull, Pearson Park	2·99	128	,,	Applecross Gardens	5·06	127
,,	Felixkirk, Mt. St. John	3·38	124	,,	Achnashellach	5·13	105
,,	York Museum	1·91	76	,,	Stornoway Airfield	3·13	109
,,	Scarborough	2·58	106	*Suth.*	Loch More, Achfary	5·32	99
,,	Middlesbrough	2·87	112	*Caith.*	Wick Airfield	3·56	135
,,	Baldersdale, Hury Res.	3·20	100	*Shetland*	Lerwick Observatory	3·49	152
Norl'd.	Newcastle, Leazes Pk.	3·28	128	*Ferm.*	Crom Castle	5·50	158
,,	Bellingham, High Green	3·82	116	*Armagh*	Armagh Observatory	4·75	164
,,	Lilburn Tower Gdns.	2·38	96	*Down*	Seaforde	6·23	195
Cumb.	Geltsdale	3·70	107	*Antrim*	Aldergrove Airfield	6·09	217
,,	Keswick, High Hill	3·41	89	,,	Ballymena, Harryville	8·93	260
,,	Ravenglass, The Grove	4·38	117	*L'derry*	Garvagh, Moneydig	6·21	192
Mon.	Abergavenny, Larchfield	5·03	202	,,	Londonderry, Creggan	6·55	179
Glam.	Ystalyfera, Wern House	7·48	163	*Tyrone*	Omagh, Edenfel	5·62	165